

*Simulation and Reconstruction  
for a multi-kton LArTPC in the  
context of the LBL study*



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# OUTLINE

- *GOAL & FEW GENERAL CONSIDERATIONS*
- *WHERE WE HAVE STARTED*
- *OUR APPROACH*
- *WHERE WE ARE NOW*
- *WHERE WE EXPECT TO BE IN OCTOBER*

# PEOPLE

- *Work presented here done by the Yale group: Colin Anderson, Steven Linden, Bonnie Fleming & myself*
- *Not happening in a vacuum - a lot of useful interaction with European (ICARUS collaboration) and American (LArTPC group) colleagues*

# GOAL

Provide a solid understanding of efficiency and background for  $\nu_e$  appearance (and  $\nu_{\mu}$  disappearance) searches with a multi-kton LArTPC, through MonteCarlo studies

# WHERE WE HAVE STARTED

- We had available a GEANT3-based MC simulation of a LArTPC which could take NUANCE files as an input (thanks to Bill Metcalf of LSU)
- We had available NUANCE v3 modified for Ar (nuclear effects)
- All this had already been used for FINESSE related studies
- No reconstruction, MC truth only
- Also, work described in NuSAG report (Tufts U.) and work done by ICARUS / Andre' Rubbia in particular

# OUR APPROACH

- Expand the existing G3 MC in order to have a viable tool to simulate events in a multi-kton LArTPC
- Use MC truth studies (and existing experimental data, known physics etc.) to estimate signal efficiency and background rejection
- Minimize the use of visual scanning
- Work on automatic reconstruction tools. Given that a lot of work needs to be done from scratch, it is unlikely that a full analysis will be ready by the end of the summer

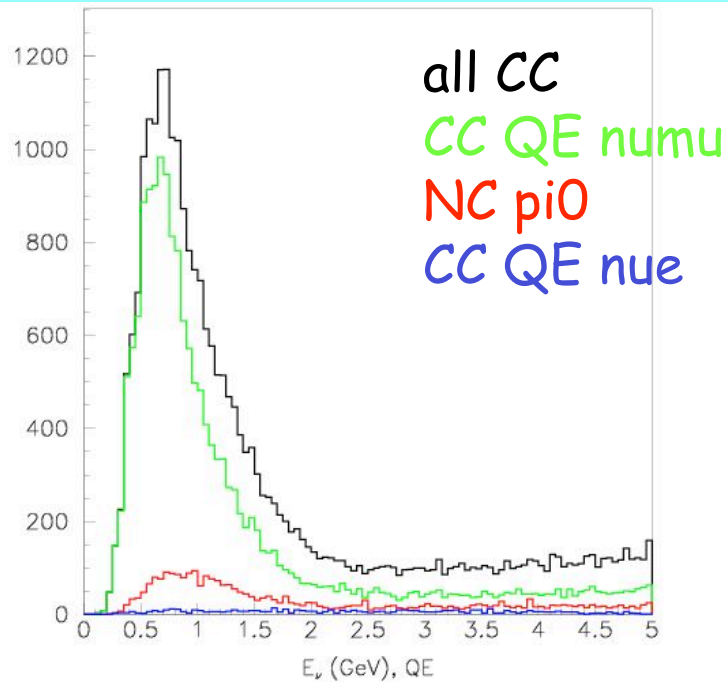
## WHERE WE ARE NOW: G3 MC

- Input for the G3 MC:
  - a) NUANCE files generated for different nu-fluxes: so far Ash River / NuMI surface building / etc. (thanks to Mark Messier) / WideBandBeam (thanks to Mary Bishai); jobs finished VERY recently, some fluxes still need to be checked etc.
  - b) Cosmic rays
  - c) Custom

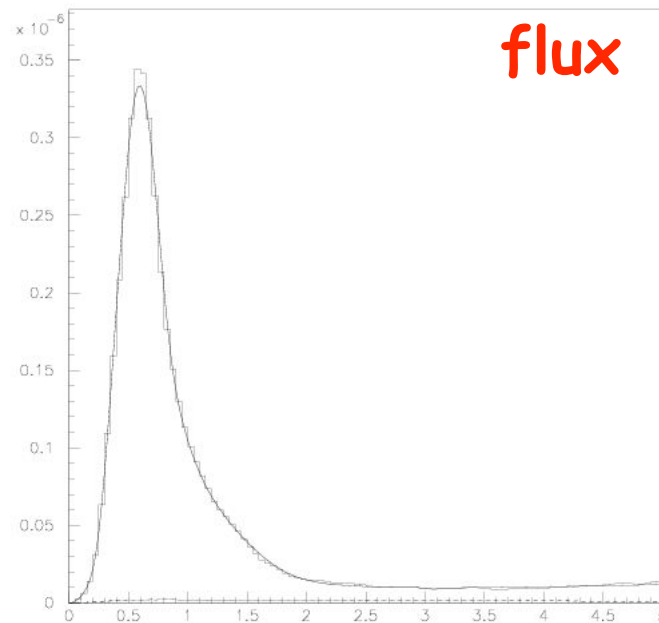
# WHERE WE ARE NOW: G3 MC [from Bonnie]

800km off-axis, 40mrad (32 km)

#of events



$\nu/\text{cm}^2/1\text{E11 POT}/50 \text{ MeV}$





## WHERE WE ARE NOW: G3 MC [from Bonnie]

location	numu CC all	numu CC QE	nue CC all	nue CC QE	NC pi0
800km 32kmOA	1.27	0.6	0.08	0.02	0.11
WBB	6.12	1.39	0.05	0.01	0.41

Event rates for 1E20, 1kton

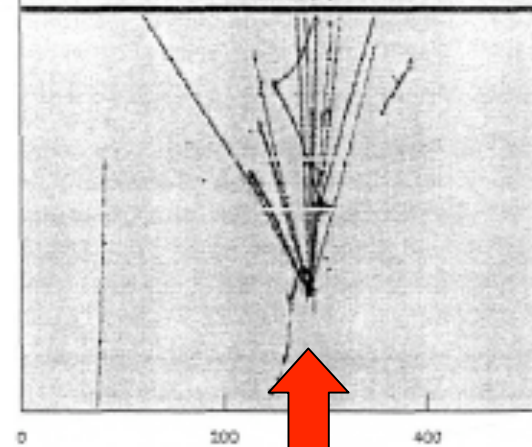
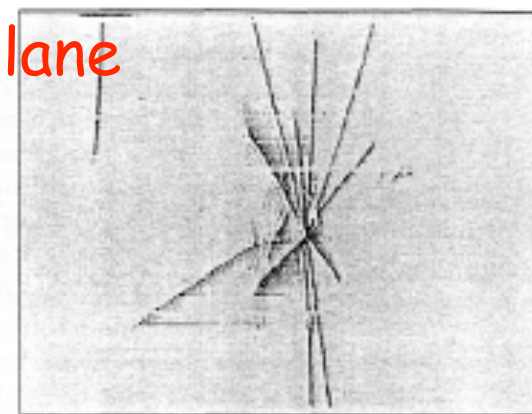
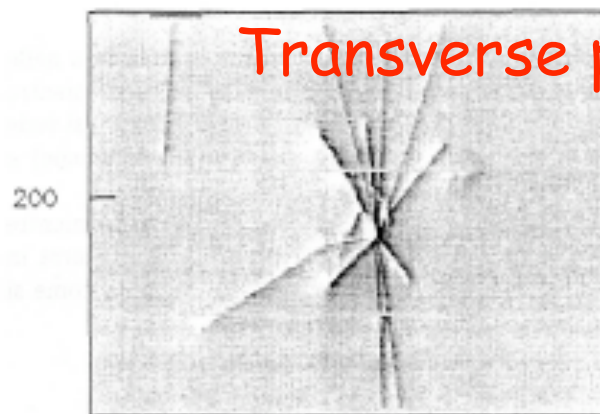
# WHERE WE ARE NOW: EXISTING EXPERIMENTAL DATA

Data from 50l LArTPC on WAND nu-beam (1997)  
(see my NuInt05 contribution / final paper in preparation)

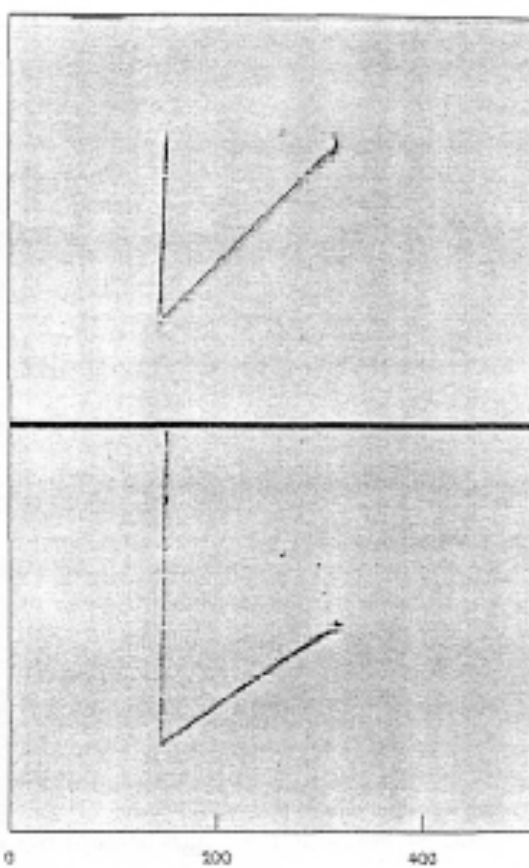
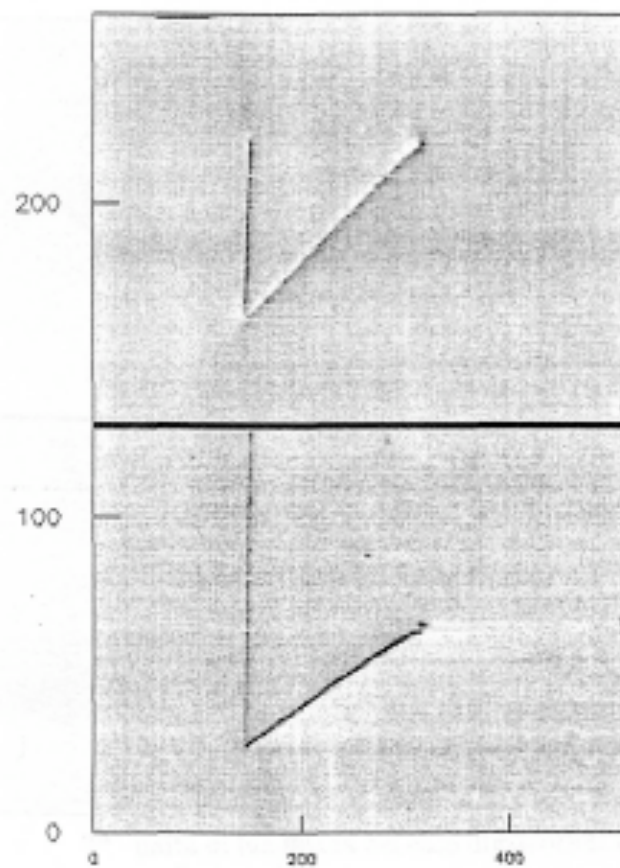
Results available from various ICARUS publications

- Protons measured down to **50 MeV** kinetic E
- Based on proton ID, can select a very pure small (1%) samples of CC QE events
- Help constraining QE kinematics
- gammas & electrons down to 10 MeV
- few cm “gaps” identified unambiguously

Transverse plane



nu-beam



CCpi0 evt.  
from 501 LArTPC  
WANF test

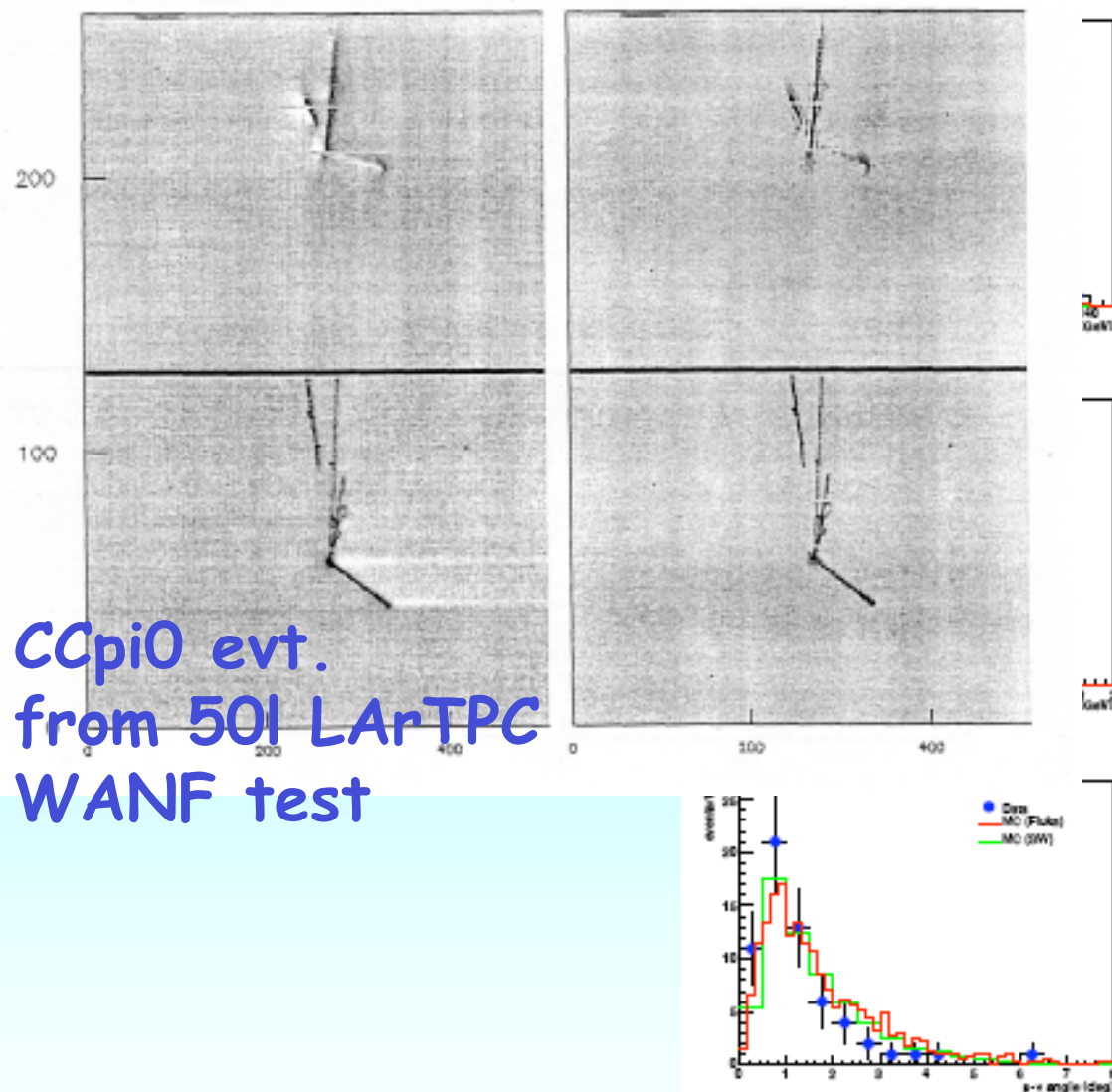


Figure 2. From top to bottom: distribution of the muon energy (3 events are out of range), muon transverse momentum and  $\mu - \nu$  angle for the golden sub-sample. The continuous red (green) line is the expectation from FLUKA (Saxon-Woods) convoluted with the detector response.

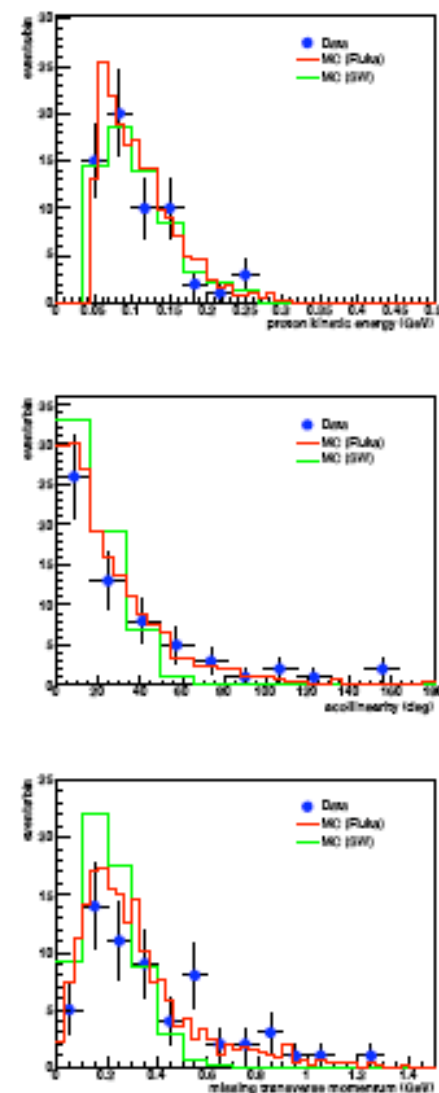
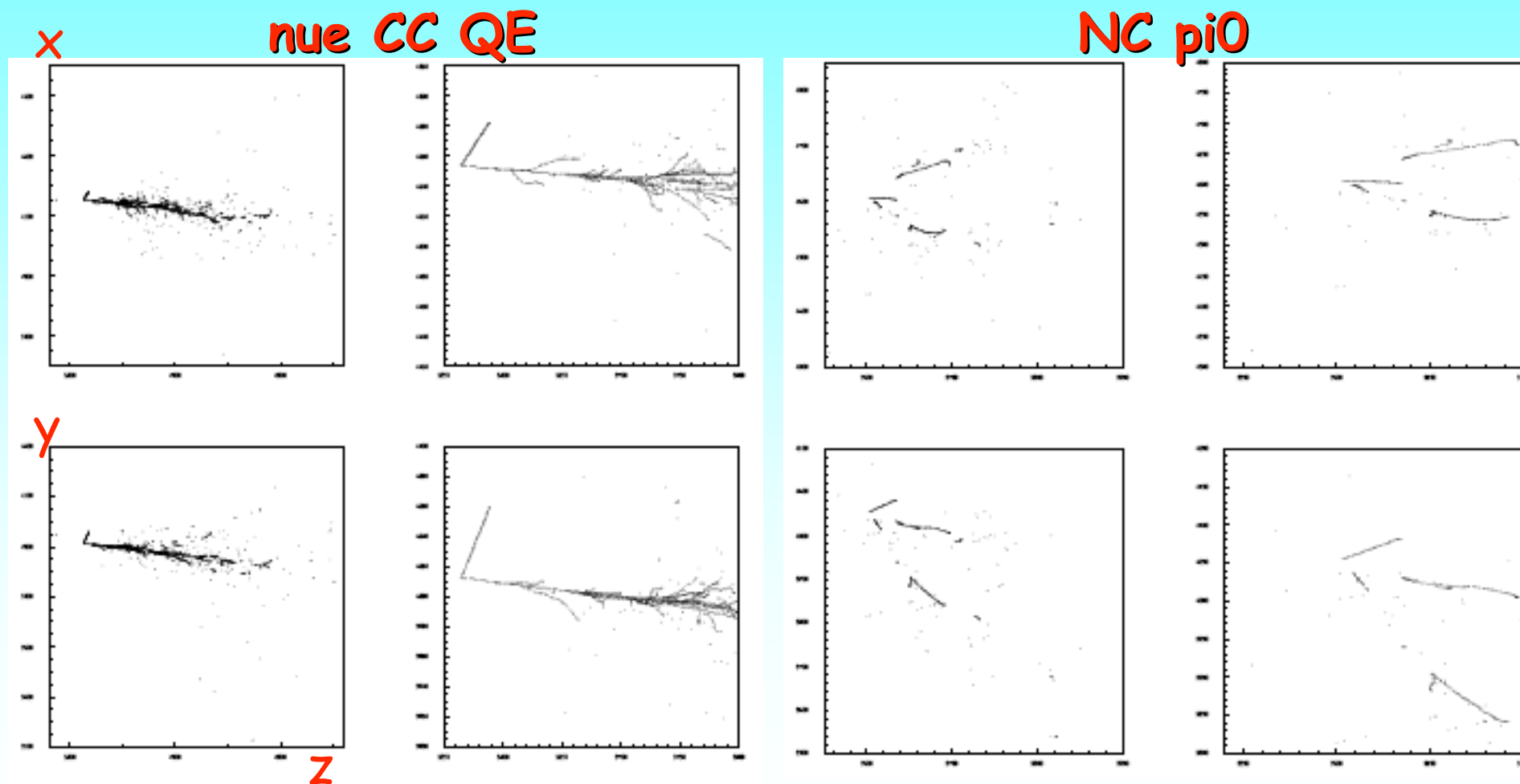


Figure 3. From top to bottom: proton kinetic energy, acollinearity and missing transverse momentum for the golden sub-sample. The continuous red (green) line is the expectation from FLUKA (Saxon-Woods) convoluted with the detector response.

## WHERE WE ARE NOW: G3 MC

- Geometry:  $10 \times 10 \times 7 \text{ m}^3$  i.e. about 1 kton of LAr
- MC provides both MC truth and digitized events for reconstruction studies
- MC has been expanded to follow gammas from  $\pi^0$  decay (MC truth)
- There're technical issues in digitizing the equivalent of a 50 kton LArTPC

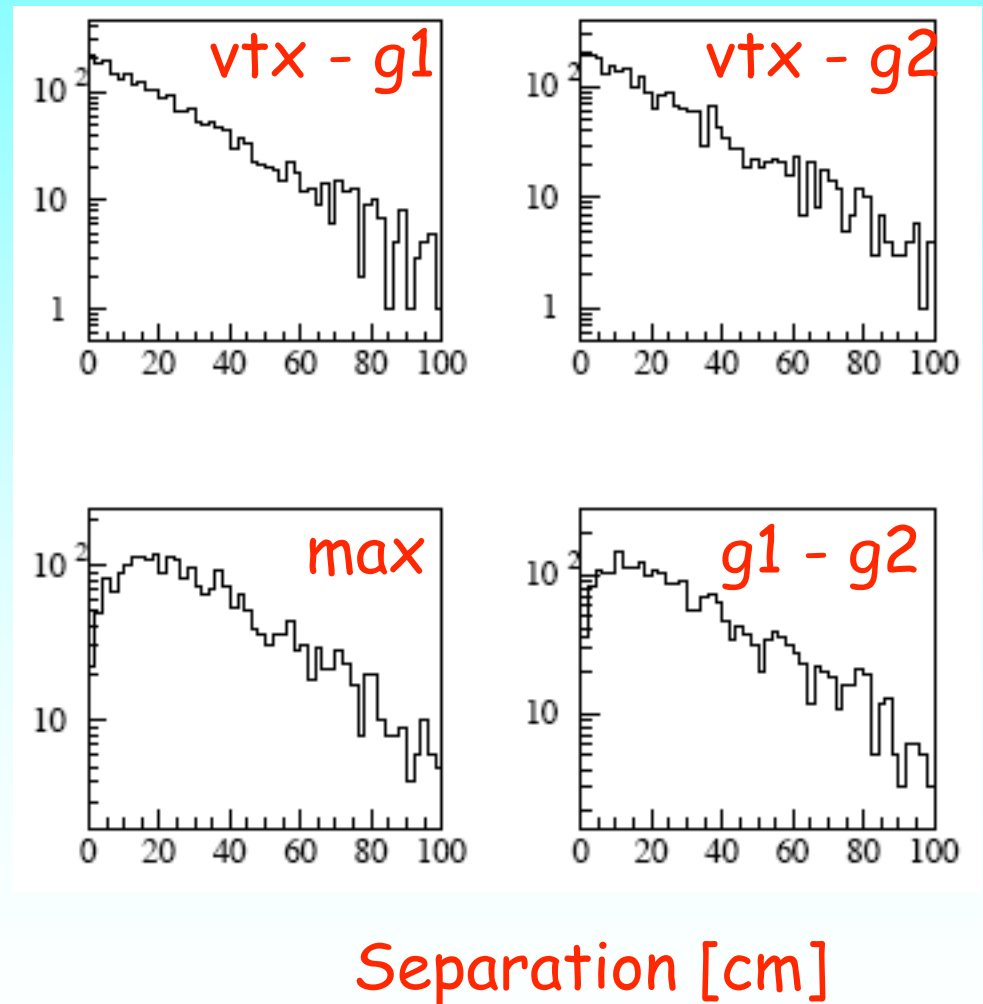
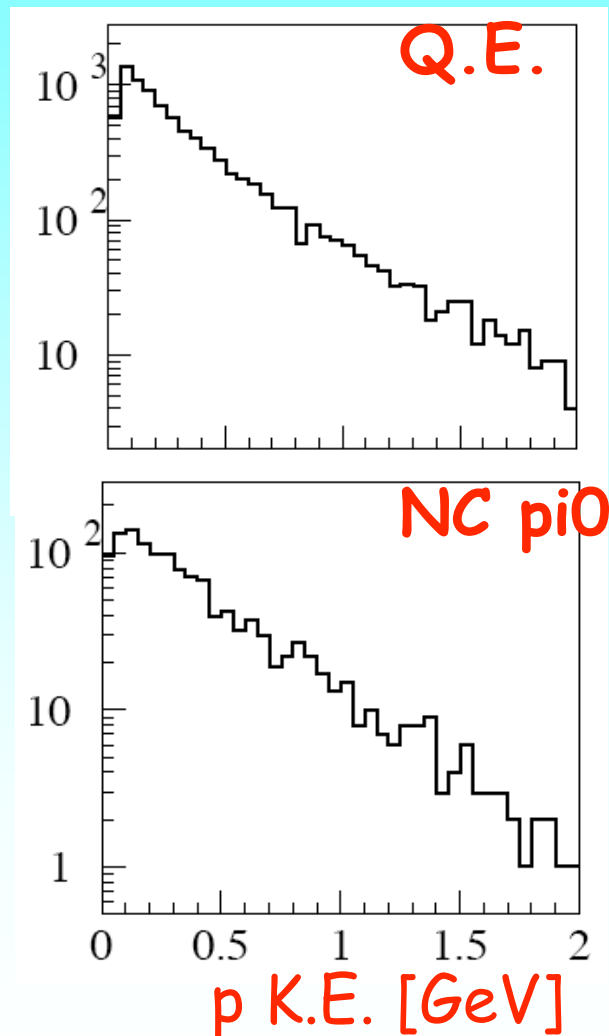
# WHERE WE ARE NOW: EFFICIENCY & BACKGROUND REJECTION [with Steven L.]



Wide band beam - 40 GeV



# WHERE WE ARE NOW: EFFICIENCY & BACKGROUND REJECTION

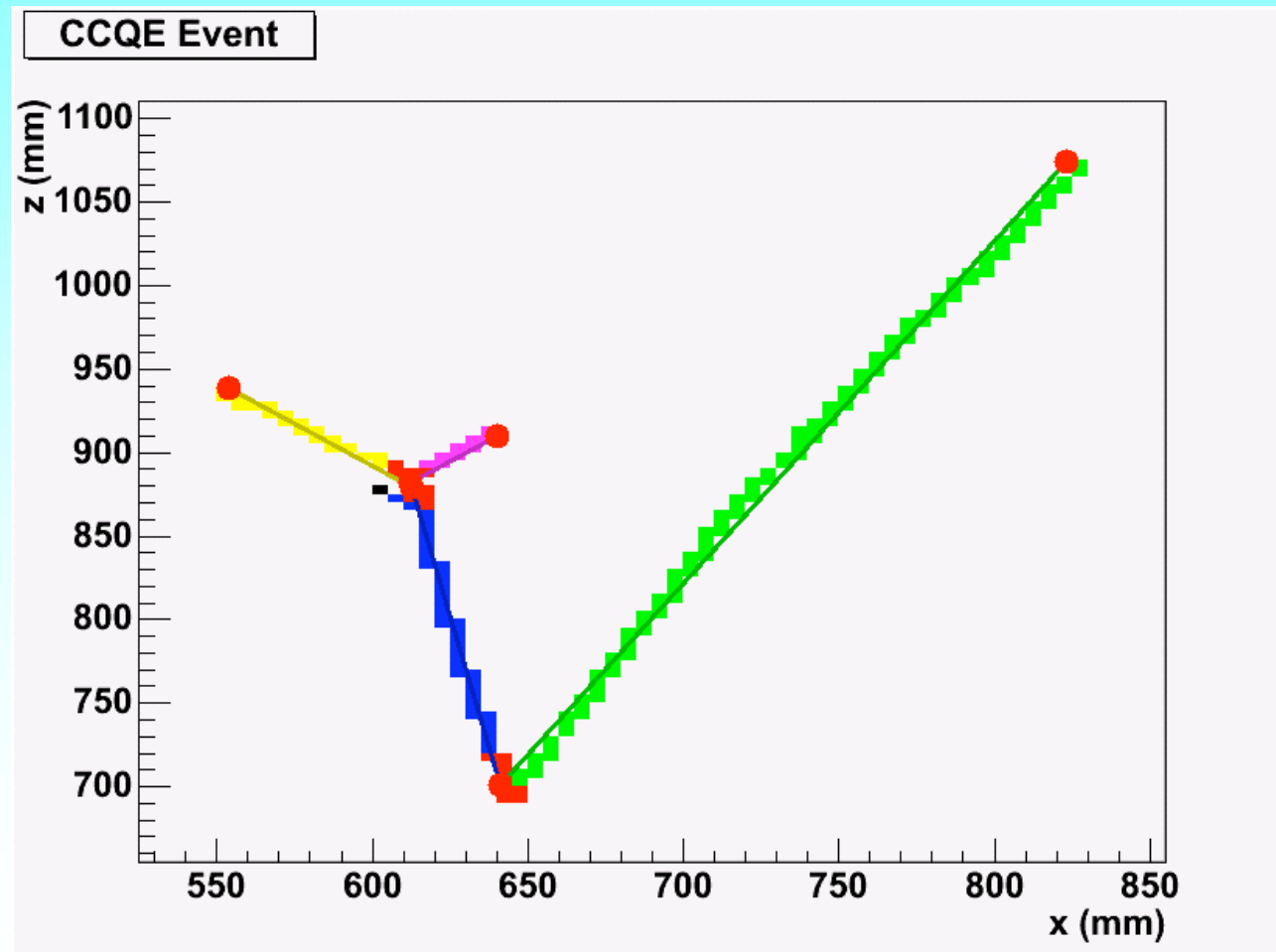


## WHERE WE ARE NOW: EFFICIENCY & BACKGROUND REJECTION

- Ask for a proton w/ kinetic energy  $> 50$  MeV to tag the vertex in a CC QE  $\nu$  interaction
- Efficiency  $> 90\%$
- Background (NC  $\pi^0$ ) rejection:
  1. About **50%** NC $\pi^0$  events have a proton in the final state w/ kinetic energy  $> 50$  MeV
  2. Asking for a gap (separation between vertex & gamma conversion point)  **$> 2\text{cm}$**  leaves **1%** of NC  $\pi^0$  events



# WHERE WE ARE NOW: AUTOMATIC RECONSTRUCTION [from Colin A.]

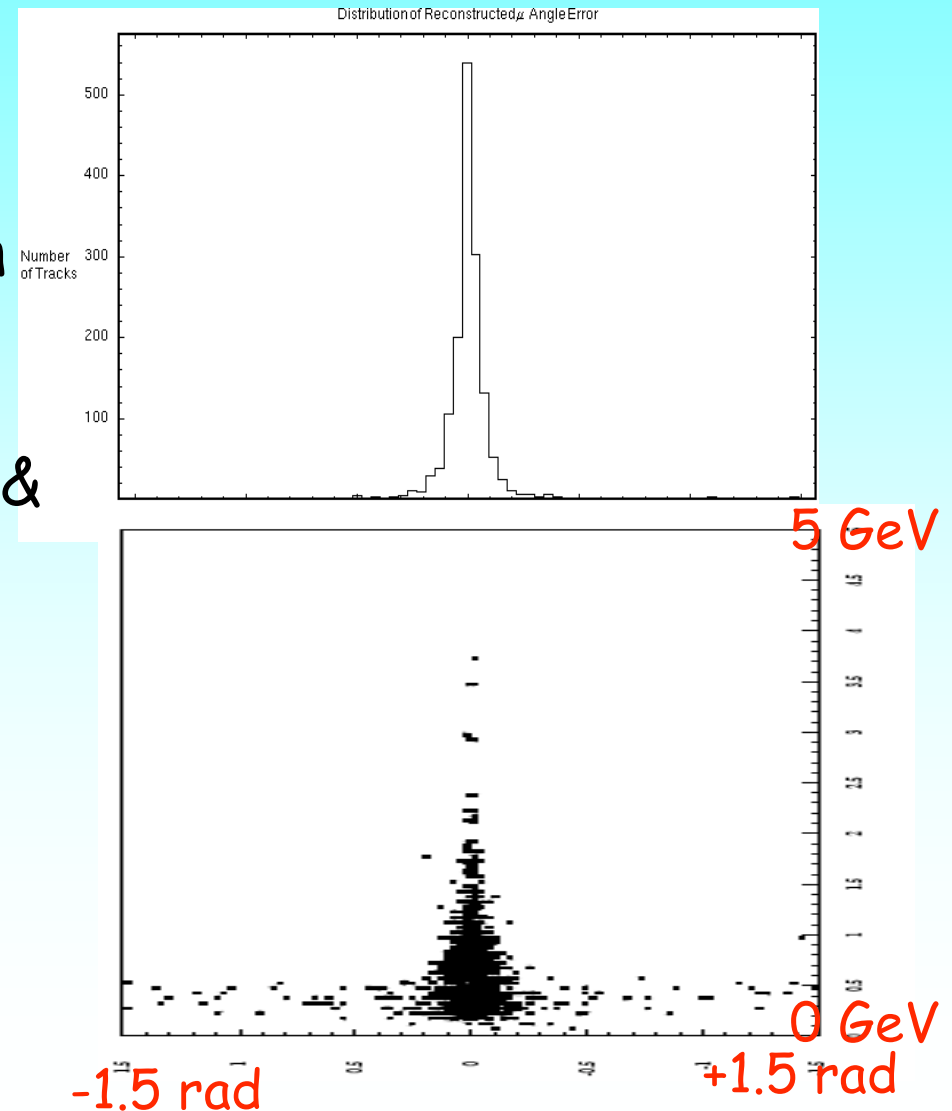


# AUTOMATIC RECONSTRUCTION

Applied to a large sample of CC QE for reconstruction of the muon direction.

As 1<sup>st</sup> pass filter, already good enough, i.e. find vertex & rough direction for muon (RMS  $\sim 2^\circ$ )

Works already well for HE ( $>1.5$  GeV) muons



## TBD: AUTOMATIC RECONSTRUCTION

- Refine reconstruction for numu CCQE
- in particular, reconstruction for low energy protons
- Start working on reconstruction of electrons, gamma and pi0 (fuzzy events)
- Start working on measuring "gaps"

# CONCLUSIONS/OUTLOOK

- Given the rate of progress so far: by mid-July we expect to make this study systematic for different nu-fluxes (including "leakage" from the HE peak off-axis)
- By October: more aggressive with efficiency (include non-QE channels) and background rejection (constraints from kinematics etc.)
- By October: first results from automatic reconstruction